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Non-Nuclear Methods Density Testing for Use in Acceptance Measures and as Related to Longitudinal Joint Issues

Prepared for
WHRP Flexible Pavement Technical Oversight Committee

Prepared by
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WisDOT Research & Library Unit

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Transportation Literature Searches are prepared for WisDOT staff and investigators to identify completed research and other authoritative information in an area of interest. The citations below are representative, rather than exhaustive, of available English-language studies on the topic. Primary online resources for the literature searches are OCLC's WorldCat and TLCat, U.S. DOT's TRIS Online, the National Transportation Library (NTL), TRB's Research in Progress (RiP) database, and other academic, engineering and scientific databases as appropriate.

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Keywords: non-nuclear density gauges, HMA, QA/QC, electromagnetic gauge, longitudinal joint, non-destructive testing.

Summary

We found 17 citations for documents published in 2002 or later, and five Research in Progress entries. Three of the citations were published in 2009, three in 2008, five in 2007, five in 2006, and one in 2002. Eight of these reports refer to state DOT studies.

Citations

Links to online copies of cited literature are provided when available. Contact the WisDOT Library to obtain hard copies of citations.

Title: Longitudinal Joint Density and Permeability in Asphalt Concrete
Author(s): Cross, Stephen A.; Bhusal, Sushanta
Date: March 2009
Source/URL: Report from Oklahoma Department of Transportation, http://www.okladot.state.ok.us/hqdiv/p-r-div/spr-rip/library/reports/fhwa-ok0807article.pdf.
Description: 4 pages
Contents: Low longitudinal joint density has been identified as one of the major issues relating to poor asphalt pavement performance. Low longitudinal joint density can lead to premature raveling of the joint and the lower density results in increased permeability of the pavement. Increased permeability allows water to easily enter the pavement resulting in increased susceptibility to moisture induced damage or stripping. The Oklahoma Department of Transportation (ODOT) does not currently have a test method or specification that addresses the problem of low longitudinal joint density. The objective of this study was to obtain the necessary field and laboratory test data to provide information around which a test method and/or specification for control of longitudinal joint density could be written. Three recently constructed pavements were selected for field testing. One pavement was on a county road and the other two pavements were ODOT construction projects. Two or three locations from each project were sampled and tested for a total of seven test sites. Field testing at each site consisted of measuring in-place

permeability, measuring pavement density using an electromagnetic device (OHD L-14 Alternate Method B) and obtaining pavement cores at five locations at each test site. Field permeameters used included an NCAT permeameter, a Kentucky air induced permeameter (AIP) and a Romus air permeameter. Laboratory permeability (OHD L-44) was determined on pavement cores. The results from pavement density testing, core density testing, field permeability testing and laboratory permeability testing were analyzed to determine relationships between field permeability, pavement density and laboratory permeability. The suitability of using field permeability at longitudinal joints for control of longitudinal joint density and permeability was evaluated.

Title: Non Destructive Technology for Quality Assurance of HMA Pavement Construction
Principal Investigator(s): Von Quintus, Harold L.
Date: 2009
Source/URL: http://144.171.11.107/Main/Public/Blurbs/162130.aspx.
Description: 111 pages
Contents: This report contains the findings of research performed to investigate the application of nondestructive testing (NDT) technologies in the quality assurance of hot mix asphalt (HMA) pavement construction. The report contains the results and analyses of the research performed and presents several key products, notably a recommended manual of practice with guidelines for implementing selected NDT technologies in an agency's routine quality assurance (QA) program for HMA pavement construction and detailed test methods for the recommended NDT technologies. Thus, the report will be of immediate interest to construction and materials engineers in state highway agencies and the private sector.

Title: Methods for Evaluating Longitudinal Joint Quality in Asphalt Pavements
Author(s): Williams, Stacy G.; Pervis, Ashly; Bhupathiraju, Leela Soujanya; Porter, Annette
Date: 2009
Source/URL: *Transportation Research Record*: Journal of the Transportation Research Board, Vol. 2098, 2009, pages 113-123.
Description: 11 pages
Contents: Longitudinal joint quality is essential to the successful performance of hot-mix asphalt (HMA) pavements. Longitudinal joints have received a considerable amount of attention recently, because many state agencies are moving toward implementation of longitudinal joint specifications. Most measures of joint quality are based on density determinations. However, distress at the joint is caused by the ability of air and water to enter the pavement structure, an action that is directly related to the permeability of the joint. In other words, density alone may not be sufficient to describe the quality of a longitudinal joint. The objective of this study was to identify the most appropriate test method or methods for describing HMA longitudinal joint quality. Three projects were selected for the study, and four testing stations were identified for each project. At each station, a number of test methods were performed at the longitudinal joint and to either side of the joint to assess the ability of each method to properly discriminate between levels of joint quality. Multiple measures of density, permeability, and gradation were obtained at each station. Overall, the methods providing the most accurate predictions of joint quality and the greatest level of discrimination were the vacuum sealing and saturated surface-dry (SSD) methods for determining the bulk specific gravity of field cores. Although measures of permeability and infiltration showed promise, it was recommended that the vacuum sealing and SSD methods for the determination of field core density be considered in the evaluation of longitudinal joint quality.

Title: Non-Nuclear Methods for HMA Density Measurements
Author(s): Williams, Stacy G.
Date: June 2008
Source/URL: University Paper from University of Arkansas,
http://www.uark.edu/rd_engr/MBTC/MBTC_2075_-_FINAL_REPORT.pdf.
Description: 77 pages
Contents: Non-nuclear methods for the measurement of hot-mix asphalt (HMA) density offer the ability to take numerous density readings in a very short period of time, without the need for intensive licensing, training, and maintenance efforts common to nuclear gauges. The Pavement Quality Indicator™ (PQI) and the PaveTracker™ use electrical impedance to estimate density. Early models of these gauges were deemed inadequate for quality control and quality assurance testing, but improvements have been made to each. In this project, a number of field sites were used to evaluate the non-nuclear gauges in terms of ruggedness, accuracy, and precision. A thorough investigation of calibration methods was also performed. In the ruggedness study, three pavement sites were used to determine potential procedural factors that significantly affected the non-nuclear density results. Moisture, the presence of sand or debris, gauge orientation, gauge type, and presence of paint markings were determined to significantly impact the accuracy of non-nuclear gauge readings. Four calibration methods were investigated,

including screed offset, core offset, two-point, and data pair techniques. None were found to possess all of the necessary components for generating significant correlations with field core densities. A screed-core method was developed as a method to more comprehensively adjust the magnitude of the offset as well as the sensitivity of the device over a large range of true densities. Overall, neither non-nuclear gauge was able to predict core densities as accurately or precisely as the nuclear gauge. Of the non-nuclear devices, the PQI generated more consistent results but was less sensitive to actual changes in density. The PaveTracker was more sensitive to actual changes in density, but exhibited a higher level of variability. Existing specifications for use of non-nuclear devices should be edited to include guidance on gauge orientation during testing, as well as calibration procedures for a screed-slope type of technique.

Title: Critical Factors Affecting Field Determination of Hot-Mix Asphalt Density Using Nonnuclear Devices
Author(s): Williams, Stacy G.; Hall, Kevin D.
Date: 2008
Source/URL: *Transportation Research Record:* Journal of the Transportation Research Board, Volume 2081, 2008, pages 150-157.
Description: 8 pages
Contents: Nonnuclear methods for the measurement of hot-mix asphalt (HMA) density offer the ability to take numerous density readings in a short time period, without the need for intensive licensing, training, and maintenance efforts common to nuclear gauges. The Pavement Quality Indicator (PQI) and the PaveTracker use electrical impedance to estimate density. Early models of these gauges were deemed inadequate for quality control and quality assurance testing, but improvements have been made to each. In this project, a ruggedness study was performed to evaluate the effects of gauge model, temperature, moisture, use of sand to fill surface voids, gauge orientation, number of replicate measurements, and gauge placement on two nonnuclear gauges. Significant factors arising from the ruggedness study were further investigated. Two 12.5-mm mixes and one 37.5-mm mix were evaluated, using 42 test locations. Gauge orientation was significant, suggesting that the test method protocol should specify gauge orientation with respect to the direction of paving. Four replicate measurements were deemed acceptable for producing a single reported result, and all sand and debris should be thoroughly brushed from the surface before testing. Moisture significantly affected the measured densities in some cases, most notably for the 37.5-mm test locations and for the PaveTracker device.

Title: Comparison of Nuclear and Nonnuclear Pavement Density Testing Devices
Author(s): Smith, Bryan C.; Diefenderfer, Brian K.
Date: 2008
Source/URL: *Transportation Research Record*: Journal of the Transportation Research Board, Vol. 2081, 2008, pages 121-129.
Description: 9 pages
Contents: The density of a hot-mix asphalt (HMA) pavement is an important factor for assessing pavement quality. Sufficient density is an essential characteristic of a well-constructed pavement and will lower its potential for distress. Traditionally, pavement density is determined by laboratory measurements of core samples and in situ readings via nuclear density gauges. Recently, nonnuclear devices that measure the electromagnetic properties of pavements have been developed. Nonnuclear devices have an inherent advantage over nuclear density gauges in that stringent monitoring of the user and extra security precautions are not required. However, the literature is unclear whether the readings from these devices are equivalent to those from nuclear density gauges. In this study, in-place pavement density readings from nonnuclear and nuclear density gauges were compared with laboratory-measured density values from core samples taken from the same location. Density readings from both gauges were compared with density measurements from the core samples for percent difference, correlation analysis, and hypothesis testing. However, the effect of moisture in the HMA was found to have a significant impact on density readings from the nonnuclear gauge. For seven of eight projects when a regression-based correction incorporating the qualitative moisture index was applied to the nonnuclear gauge density readings, the densities were better correlated to core density measurements than were densities from a traditionally used nuclear density gauge. On the basis of this study, the nonnuclear density gauge is more suitable than the nuclear density gauge for measuring pavement density on dense-graded HMA, provided that the readings are corrected using the qualitative moisture index.

Title: Non-Nuclear Compaction Gauge Comparison Study
Author(s): Brown, Jeffrey
Date: December 2007
Source/URL: Report from Vermont Agency of Transportation, http://www.aot.state.vt.us/matres/Documents/ACROBAT.pdf/S&FDox/AOT-Non-NuclearCompactionGaugeComparisonStudy-FinalReport.pdf.
Description: 16 pages
Contents: The following report summarizes the Certification and Independent Assurance Unit's efforts in conducting a comparison study of performance and usability between a nuclear compaction gauge and two non-nuclear compaction gauge alternatives. During the course of the 2007 construction season, in cooperation with Program Development's Construction Section and Operations' Maintenance Section, various materials were tested for in-place moisture and density. The various materials tested were used in both roadway subbases and structural backfills. The Certification and Independent Assurance Unit's interest in the non-nuclear compaction gauge alternatives is two-fold. First, they are capable of being transported and used anywhere without the concerns and regulations associated with nuclear safety, and second, they do not accrue the substantial financial costs associated with the ownership of nuclear compaction gauges. These costs include training and certifications for technicians, semi-annual leak tests, yearly verifications, and bi-annual calibrations; along with licensing, storage, special handling, and shipping of a hazardous material.

Title: Evaluation of Nonnuclear Density Tests on Hot Mix Asphalt Segregation
Author(s): Chang, C.; Chen, J.; Fang, C.; Chang, M.
Date: June 2007
Source/URL: *Journal of Testing and Evaluation*, Vol. 35, No. 6.
Description: 8 pages
Contents: Since the identification of segregation on asphalt pavements has been based on visual observations around the world, it is essential to develop a quantitative method to detect the presence and severity of segregation. The nonnuclear density device was selected for the field measurements at nine test sites, and cores were taken for laboratory testing. The nonnuclear density difference between segregated and control areas was found to increase with increasing the segregation severity. For medium or heavy segregated areas, the nonnuclear density difference was more than 90 kg/m^3. In medium or heavy segregated areas, the air voids increased by 20 percent and the indirect tensile strength decreased by 8 percent as compared to the control areas. The criterion to detect segregation was based on the statistical differences in nonnuclear measured density values with a p-value 0.05. If a statistical difference in nonnuclear density between segregated and control areas existed, the chance of aggregate gradation difference in percent passing the 3/8 in., No. 4 and No. 8 sieves for medium and heavy segregation was 78 percent and 64 percent, respectively. In addition to the field nonnuclear density readings, the material properties of asphalt mixtures obtained from 108 cores, including texture depth and percent air voids, were selected as independent variables to develop a model to predict the calibrated nonnuclear density difference between the segregated and control areas. This quantitative model holds a great promise as a tool to identify potential areas of segregation using both lab data and field nonnuclear density measurements for quality assurance purposes.

Title: Investigation of Electromagnetic Gauges for Determining In-Place HMA Density
Author(s): Kvasnak, Andrea N.; Williams, R. Christopher; Ceylan, Halil; Gopalakrishnan, Kasthurirangan
Date: May 2007
Source/URL: Report from Iowa Department of Transportation, http://publications.iowa.gov/5288/1/tr547.pdf.
Description: 89 pages
Contents: Density is an important component of hot-mix asphalt (HMA) pavement quality and long-term performance. Insufficient density of an in-place HMA pavement is the most frequently cited construction-related performance problem. This study evaluated the use of electromagnetic gauges to nondestructively determine densities. Field and laboratory measurements were taken with two electromagnetic gauges—a PaveTracker and a Pavement Quality Indicator (PQI). Test data were collected in the field during and after paving operations and also in a laboratory on field mixes compacted in the lab. This study revealed that several mix- and project-specific factors affect electromagnetic gauge readings. Consequently, the implementation of these gauges will likely need to be done utilizing a test strip on a project- and mix-specific basis to appropriately identify an adjustment factor for the specific electromagnetic gauge being used for quality control and quality assurance (QC/QA) testing. The substantial reduction in testing time that results from employing electromagnetic gauges rather than coring makes it possible for more readings to be used in the QC/QA process with real-time information without increasing the testing costs.

Title: Implementation of Electro-Magnetic Gauge Readings for Assessing Hot Mix Asphalt Quality
Author(s): Kvasnak, Andrea; Williams, R Christopher
Date: 2007
Source/URL: Conference Proceeding Paper from Fifty-Second Annual Conference of the Canadian Technical Asphalt Association (CTAA), 2007, pages 21-38.
Description: 18 pages
Contents: This paper, from the proceedings of the 52nd Annual Conference of the Canadian Technical Asphalt Association (CTAA), describes the use of electromagnetic gauge readings for assessing hot mix asphalt (HMA) quality. The authors note that insufficient density of an in-place HMA pavement is the most frequently cited construction related performance problem. Density is measured as part of the quality control process by the paving contractors and for the quality assurance process by owner/agencies. However, the current practice of using cores taken from the roadway and measure in the laboratory creates imperfections in new pavements. Laboratory measurement of core samples is also time-consuming and costly. After the authors outline the need for a rapid, non-intrusive, non-destructive, and non-radioactive method for HMA density measurement, that is also easy to use and reliable, they consider the potential of using electromagnetic gauges. They contend that presently available electromagnetic gauges have the potential to replace nuclear density gauges and address many of the issues associated with the coring process. Two gauges are reported on: the Pavement Quality Indicator (PQI, Trans-Tech Systems) and the PaveTracker (Troxler Electronics Laboratories). The remainder of the paper discusses how electromagnetic gauges can be affected by several variables, including aggregate type, binder content, nominal maximum aggregate size, traffic level, and the presence of moisture. The gauges were also found to be sensitive to the number of roller passes, which is related to the percentage of maximum density. The authors conclude that electromagnetic gauges can be used successfully for assessment purposes when they are calibrated utilizing a test strip on a project/mix basis. Both instruments were found to be easy to use in the field and both generally agreed with the findings resulting from the standard core method.

Title: Calibration of Nonnuclear Density Gauge Data for Accurate In-Place Density Prediction
Author(s): Rao, Chetana; Von Quintus, Harold; Schmitt, Robert L.
Date: 2007
Source/URL: *Transportation Research Record:* Journal of the Transportation Research Board, Vol. 2040, 2007, pages 123-136.
Description: 14 pages
Contents: Hot-mix asphalt (HMA) density is an important acceptance quality characteristic, which involves in situ tests for quality control and assurance (QC/QA). Highway agencies have conventionally used nuclear density gauges or core samples for mat density. More recently, alternate nondestructive testing methods have been considered to replace current test methods. Nonnuclear density gauges offer rapid testing while eliminating safety risks and costs associated with radioactive license. Although agencies have evaluated them, they are not implemented in acceptance testing so far. Results are presented from a field evaluation of three nonnuclear density gauges—PaveTracker, PQI 300, and PQI 301—conducted on Wisconsin Department of Transportation (WisDOT) paving projects. The main goal was to evaluate the performance and effectiveness of nonnuclear gauges for use in QC/QA activities by WisDOT. The study involved field tests at 16 project sites and included 21 mix designs and a variety of mix design and pavement design parameters, such as aggregate type, nominal maximum aggregate size, layer thickness, design traffic, and base type. Density measurements were recorded at 30 test points at each site with one nuclear gauge and three nonnuclear gauges. Although the mean standard deviation values of the nonnuclear gauge data were less than those of the nuclear gauge measurements, a consistent bias was observed between the two data sets. This bias was adjusted by using a calibration factor to yield density predictions statistically the same as the nuclear gauge measurements. It is recommended that a calibration factor determined from 10 points by using a slope function be implemented for agency use. Further, daily calibration for each mix design is recommended when the project involves multiple paving days.

Title: Quantifying Segregation in HMA Pavements Using Non-Nuclear Density Devices: Data Collection Report for Connecticut
Author(s): Larsen, Donald A.; Henault, John W.
Date: November 2006
Source/URL: Report from Connecticut Department of Transportation, http://www.ct.gov/dot/LIB/dot/documents/dresearch/CT-2238-F-06-2.pdf.
Description: 32 pages
Contents: This ConnDOT project complements the National Pooled Fund Study, SPR-3(082), Phase II. Phase II was to develop a method to quantify the level of volume segregation in HMA pavements using density profiles

obtained from non-nuclear (electromagnetic) density gauges. The purpose of the ConnDOT project was to collect field density data on newly placed HMA pavements for submittal to the Pooled Fund contractor (University of Utah) and to evaluate the ability of two non-nuclear devices to collect data for determining severity of pavement segregation in Connecticut. Two locations were used for the evaluation: I-84 Waterbury and Route 66, Middlefield, CT. Density measurements were made within a pre-defined grid, using the two devices (and a nuclear density gauge at one of the sites (Route 66)). Cores were cut and removed from areas thought to represent low, medium and high density areas within the grids, as determined by the various gauges. The cores were sent to the University of Utah for analysis of gradation, air voids and asphalt content. The results indicate that the density variations measured with the non-nuclear devices were not very useful for determining volume segregation or uniformity at these two project sites.

Title: Measurement of Longitudinal Joint Density in Asphalt Pavements Using Nuclear and Nonnuclear Gauges
Author(s): Troxler Jr., William F.; Dep, Linus
Date: September 2006
Source/URL: *Transportation Research E-Circular*, Issue No. E-C105, pages 100-119, http://worldcat.org/issn/00978515.
Description: 20 pages
Contents: Several studies have shown that the long-term performance of asphalt pavement near a longitudinal joint can be predicted by the material density near the joint just after construction. However, the asphalt material near a joint is less homogeneous than the material in the middle section of a lane. As a result, estimating the density of a joint requires obtaining density measurements at several different locations. Density gauges that employ nondestructive methods are excellent tools for this purpose. This paper outlines the key features of both nuclear and nonnuclear density gauges that can be used to measure density near longitudinal joints in asphalt pavements. It discusses the gauge properties, such as precision, lateral extent of measurement, depth of measurement, effect of an air gap between the pavement surface and the gauge, and absolute density. A good understanding of gauge properties will assist the user in selecting the proper gauge for the specific job.

Title: Non-Nuclear Density Testing Devices and Systems to Evaluate In-Place Asphalt Pavement Density
Author(s): Schmitt, Robert L.; Rao, Chetana; Von Quintus, H. L.
Date: May 2006
Source/URL: Report from Wisconsin Department of Transportation, http://www.dot.wisconsin.gov/library/research/docs/finalreports/05-10nonnuclear-f.pdf.
Description: 131 pages
Contents: A field evaluation of portable non-nuclear density gauges was conducted to determine their effectiveness and practicality for quality control and acceptance of asphalt pavement construction. Three portable non-nuclear gauge models were evaluated, including the TransTech PQI Models 300 and 301, and Troxler PaveTracker 270 lb. All non-nuclear models consistently read lower than the nuclear density gauge. PQI Model 301 read 11.2 to 27.2 pcf lower than the nuclear gauge; PQI Model 300 ranged from 4.2 to 26.6 pcf lower; PaveTracker varied from 1.8 to 17.7 pcf lower. An analysis of variance determined that several factors affected the difference between the nuclear and non-nuclear readings, and it was recommended that a calibration be conducted uniquely for each project to block the effect of the factors. A daily calibration to the nuclear density gauge was recommended using a 10-point calibration slope functions, since it has less error and more simplistic approach for field purposes. The current nuclear density specification was reviewed and analyzed, and it was determined that the current n=7 sample size yielded a confidence interval of ± 1.5 pcf, and ± 0.9% density. It was recommended that adjustments be made to the current specification if risk levels are to be reduced. Sample size for non-nuclear gauge testing for a given lot on project was determined to be n=30 test sites, based on a 95% confidence level, mat and slope-function error, and confidence intervals of ± 1.0 pcf and ± 0.6% density. A statistically-based procedure for determining the allowable difference between density gauges was detailed. When independent sites are used for non-nuclear test comparisons, 30 test sites are necessary to achieve a true difference of 1.0 pcf, based on the pooled variance, alpha risk of 5%, and beta risk of 20%. When the same test sites are used for comparison (split sample), 10 comparison test sites are necessary at the same risk levels. Finally, issues to consider for implementing the non-nuclear test specification were detailed, including nuclear density gauge requirement, operator familiarity with the devices, battery charging, adhering to manufacturer recommendations, computing the slope function, test site layout, and training.

Title: Support for the Implementation of a Longitudinal Joint Density Specification for Hot-Mix Asphalt Concrete
Author(s): Estakhri, Cindy K.
Date: January 2006
Source/URL: Report from Texas Department of Transportation, http://tti.tamu.edu/documents/5-1757-01-1.pdf.
Description: 20 pages
Contents: Research project 0-1757 assessed the density of the longitudinal construction joint of many pavements in Texas and identified that a significant joint density problem existed, which justified the implementation of a joint density specification. This specification is now included as part of the Standard Specifications for Item 341 (Dense-Graded Hot-Mix Asphalt). To facilitate the implementation of the research and specification, the following objectives were included in this implementation project: identify the most promising construction techniques aimed at achieving longitudinal joint density; develop and conduct training seminars for the districts on construction of longitudinal joints and on the new TxDOT testing and specification requirements; acquire non-nuclear density gauges; and evaluate current longitudinal joint density criteria and the ability of contractors to meet the criteria. Project 0-1757, which provided the background supporting the need for a longitudinal joint density specification, reported densities near the unconfined edge averaging 6 to 7 lb per cubic foot below the densities taken at the center of the mat. Since the implementation of a joint density specification, a significant improvement in the longitudinal joint density has been observed. Data from some of the projects presented herein indicate a joint density of only 1.0 pcf (or less) below the density of the mat interior.

Title: Non-Nuclear Density Gauge Comparative Study for QC/QA in HMA Construction
Author(s): Liao, Y.; Sargand, S.; Kim, S.
Date: 2006
Source/URL: Conference Proceeding Paper from Airfield and Highway Pavements Specialty Conference, 2006, pages 365-376.
Description: 12 pages
Contents: This paper presents the study to characterize the performance of a new non-nuclear density gauge for real-time determination of in-place density of asphalt pavements using the PaveTracker™ (PT). Laboratory results indicated that significant factors affecting the PT gauge readings were mix type, surface moisture content, internal moisture content, and pavement thickness in relation to the probing depth of the PT gauge. The size of the surface area of the specimen was also a significant factor affecting the PT reading. From the field study, it was found that the densities measured using the PT gauge were statistically different from core densities and nuclear densities. When a pay factor schedule being used by Ohio Department of Transportation was applied to the field projects, the three types of density measurements (nuclear, non-nuclear, and coring methods) resulted in slightly different pay factors. It was recommended that the non-nuclear methods for in-place density may be useful for QC purposes but not for QA testing.

Title: Evaluation of New Nonnuclear Pavement Density Gauges with Data from Field Projects
Author(s): Romero, Pedro; Kuhnow, Frederick
Date: 2002
Source/URL: *Transportation Research Record*: Journal of the Transportation Research Board, Vol. 1813, 2002, pages 47-54.
Description: 8 pages
Contents: The introduction of new devices to measure pavement density requires an evaluation method that is both accurate and fair. Evaluations are commonly done by taking a density measurement with the gauge and comparing this density to the density obtained from a core taken at the same location. This approach must meet two requirements; first, enough cores must be taken at each location to make the comparisons meaningful, and second, evaluation of these devices must be done with as many projects in as many locations as possible to account for all materials used in pavement construction. Unfortunately, given the difficulties in obtaining field cores, large numbers of cores that can be used for evaluations are not available from all projects. Therefore, any evaluation of density gauges must balance rigor with practicality. The correlation coefficient was selected to evaluate the new nonnuclear pavement density gauge. However, because only a limited number of cores are available at each site for development of the correlation coefficient, this parameter by itself cannot be used to evaluate the new gauge. Instead, results from side-by-side comparisons with the accepted nuclear density gauge were used to aid in the evaluation of the new density-measuring device. It was concluded, on the basis of data from 76 projects in six different states, that the proposed nonnuclear density gauge must be further developed before it can be used to determine pavement density. In its current form, the densities obtained with the device do not correlate with the measured densities to the same degree that the densities measured with existing devices do. Use of this nonnuclear device will introduce more uncertainty in pavement density measurements than that which already exists.

Research in Progress

Title: An Evaluation of the Potential Use of Non-Nuclear Pavement Density Testing Devices for Hot-Mix Asphalt (HMA) Acceptance
Principal Investigator(s): None listed yet.
Start Date: November 2009
RIP URL: http://rip.trb.org/browse/dproject.asp?n=23798
Sponsor Organization: Virginia Department of Transportation
Contents: This study will determine if two new non-nuclear density gauges (PaveTracker Plus and PQI 301) are equally or better suited for hot-mix asphalt acceptance as currently specified nuclear gauges. Non-nuclear density gauges contain no radioactive source materials. The Virginia Department of Transportation (VDOT) follows Virginia Test Method 76 for hot mix asphalt (HMA) acceptance in the field. This specifies a two-step procedure with both a control strip and the mainline pavement (the rest of the works besides the control strip). Within the control strip, a nuclear density gauge measures the pavement density at 10 stratified random locations. Next, cores or plugs are collected at the three locations where the density reading is nearest the average nuclear density gauge reading. If the average density is acceptable, the control strip is accepted as part of the permanent works. The average density gauge reading of the 10 stratified random locations—the target density—forms the basis for acceptance of the remainder of the project.

Title: Non-Nuclear Methods for HMA and Soil Density Measurements
Principal Investigator(s): Cho, Yong, University of Nebraska
Start Date: July 2009
RIP URL: http://rip.trb.org/browse/dproject.asp?n=23059
Sponsor Organization: Federal Highway Administration
Contents: In-place density is a key indicator used to judge the quality of hot-mix asphalt (HMA) pavements. Traditionally, this property has been measured by determining the density of cores cut, or by the use of nuclear gauge. Core densities are typically believed to provide the most accurate results, but this process is destructive to the newly compacted pavement. Also concerns have been expressed regarding the accuracy of core method, especially for coarse-graded and large nominal aggregate size (NMAS) mixes. Soil density and moisture content are two essential properties in the quality control and quality assurance of projects that involve soil compaction. However, current field practices either are destructive and time-consuming, sand cone or water balloon for soil density and oven drying for moisture content. Nuclear technology offers a non-destructive method for density measurements, but is burdened with high costs and intense regulations associated with training and certifications for technicians, semi-annual leak tests, yearly verifications, and bi-annual calibrations; along with licensing, storage , special handling, and shipping of hazardous materials. The goal of the research is to assist the Nebraska Department of Roads (NDOR) with supporting technical data in order to adopt non-nuclear gauges as a test modality for assessing HMA pavement and in-place soil. As a step toward this goal, the objectives of this research are: 1) to assess the effect of a considerable number of factors potentially affecting the density and moisture measurements generated by non-nuclear gauges on HMA and soil compared to the nuclear gauge and core/soil samples through intensive field and lab tests; and 2) to investigate economical alternatives, such as trade-in, for replacing the current NDOR nuclear gauges to minimize NDOR's cost burden.

Title: Infrared Thermography-Driven Detection and Evaluation of Hot Mix Asphalt (HMA)
Principal Investigator(s): Kim, Yong-Rak, University of Nebraska, ykim3@unl.edu
Start Date: July 2007
RIP URL: http://rip.trb.org/browse/dproject.asp?n=13596
Sponsor Organization: Nebraska Department of Transportation
Contents: The main objective of this research project is to investigate variables which have a significant effect on HMA mix temperature segregation during roadway construction using an infrared thermal image camera and a non-nuclear density gauge. The study expects to accomplish the main goal by pursuing the following four specific objectives to: (1) evaluate the possible reasons for the occurrence of thermal differentials during HMA construction process, (2) develop a practical and economical method of preventing and managing HMA thermal differentials, (3) validate the effectiveness of infrared thermal images as a test modality for assessing thermal differentials in HMA, and (4) validate the effectiveness of non-nuclear density gauge as test modality for assessing HMA densities.

Title: Development of Field Correlation and Test Procedure for TransTech Systems' Pavement Quality Indicator (PQI) 301 Non-Nuclear Density Gauge
Principal Investigator(s): Zaman, Musharraf, University of Oklahoma, zaman@ou.edu
Start Date: July 2006
RIP URL: http://rip.trb.org/browse/dproject.asp?n=12543
Sponsor Organization: Oklahoma Department of Transportation
Contents: The objective of this project is to develop and correlate a calibration and testing procedure for TransTech Systems' Pavement Quality Indicator (PQI) 301 Non-Nuclear Density Gauge.

Title: Investigation of Electro-Magnetic Gauges for Determination of In-Place Density of HMA Pavements
Principal Investigator(s): Williams, Chris; Ceylan, Halil; University of Kentucky
Start Date: November 2005
RIP URL: http://rip.trb.org/browse/dproject.asp?n=11331
Sponsor Organization: Iowa Department of Transportation
Contents: The primary objective of this research is to establish the accuracy and precision of the PQI model 301 electro-magnetic gauge manufactured by Trans-Tech and the PaveTracker model 2701 electro-magnetic gauge manufactured by Troxler as compared to cores. The secondary objective is to investigate the use of these gauges for determining differences in density at and near the longitudinal joint and in areas of segregation, when observed.